

SPATIAL-TEMPORAL DISTRIBUTION AND GROWTH OF *MERLUCCIIUS MERLUCCIIUS* RECRUITS IN THE LIGURIAN SEA. OBSERVATIONS ON THE 0 GROUP.

by

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ABSTRACT. - The recruits of *Merluccius merluccius* were studied in their distribution according to time and space. In a monthly sampling lasting about two years on littoral bottoms two main recruitments were observed each year, in the spring and in the autumn. On the basis of a stratified sampling effected between 0 and 700 m the nurseries (i.e. bottoms where the fish lives its first year of life) were located at levels between 50 and 250 m with the youngest fish concentrated near the 100 m level. A daily growth curve for 0 group fish is given. In contrast to the adults this fish lives in relatively constant environmental conditions.

RÉSUMÉ. - La distribution des recrues de *Merluccius merluccius* a été étudiée dans le temps et dans l'espace. Grâce à un échantillonnage mensuel pendant deux ans environ, deux recrutements principaux ont été observés chaque année sur les fonds littoraux, l'un au printemps, l'autre en automne. Sur la base d'un échantillonnage stratifié effectué entre 0 et 700 mètres, les «nurseries» (c'est-à-dire les fonds où les poissons vivent leur première année) ont été localisées entre 50 et 250 mètres, les poissons les plus jeunes étant concentrés à près de 100 mètres. Une courbe de l'accroissement journalier est donnée pour les poissons du groupe 0. Contrairement aux adultes, ces poissons vivent dans des conditions relativement constantes.

Key-words : Gadidae, *Merluccius merluccius*, MED, Ligurian Sea, Spatial-temporal distribution, Growth, Recruitment.

Although there have been numerous studies on the biology of the Mediterranean hake, a recent F.A.O. report points to the following questions as ones which have not yet been examined in sufficient depth: the sexual cycle of adults during the course of the year; the distribution of larvae in the ichthyoplankton; the timing of the recruits' descent to the bottom (C.G.P.M. 1982).

The purpose of this paper is to provide data on the recruitment of *Merluccius merluccius*. A Ministero della Marina Mercantile programme on the protection of fish juveniles along the coastal strip (1982-83) made it possible to study the timing of recruitment because of the monthly sampling rhythm, the systematic exploration of neritic levels and, finally, the use of a particularly tightly meshed net. A second national campaign financed by the Ministero della Marina Mercantile and which is still in progress has provided the opportunity to collect some initial data on the spatial distribution of recruits.

MATERIALS AND METHODS

In 1982-83 samples were taken at monthly intervals from the trawlable bottoms situated on the Eastern Ligurian Riviera roughly off the coast at Chiavari (Fig. 1) using professional equipment hired for the purpose from the Santa Margherita fishing fleet: a trawler of 18 tons gross tonnage, equipped with a 150 Hp engine, echo-sounding gear and radar and a 3-men crew. The net was an otter-trawl, belly 400 meshes of 25 mm side, lower body 120 meshes of 30 mm, wings 200 meshes of 45 mm, cod end 420 meshes of 6 mm side, lower and upper edge each 70 meshes of 35 mm; sweep lines of 200 m, warps of 250-1000 m, otter board of 100x170 cm.

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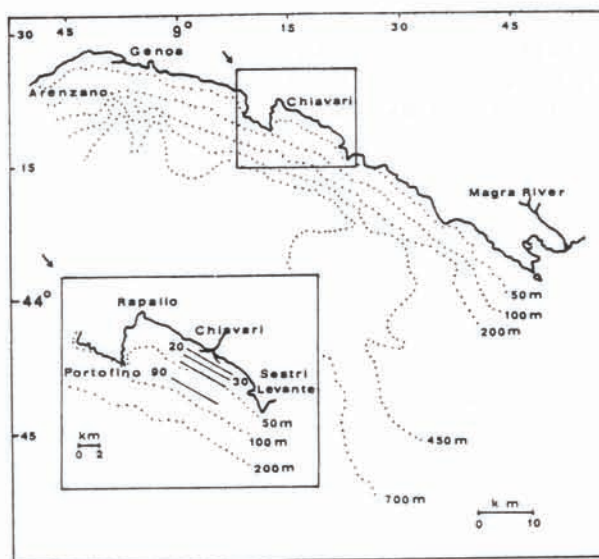


Fig. 1: Sampling areas of the «Evaluation of demersal resources» programme for 1985-86 and (square) during the 1982-83 M.M.M. programme.

Each monthly sampling consisted of 4 one-hour effective trawls, carried out, during day-light hours, at the following depths: -20, -30, -50 and -90 m. Other occasional samples were taken at depths of -10, -85 and -300.

Other observations on recruitment are taken from the 1985-86 programme on the «Evaluation of demersal resources» financed by the Ministero della Marina Mercantile (Relini, 1985).

The trawlable bottoms in a vast area situated between Arenzano and the mouth of the Magra (Fig. 1) and depths between 0 and 700 m were sampled using 56 one-hour daytime trawls. These were divided into five depth levels (-50, -100, -200, -450 m) in numbers proportionate to the extension of the bottoms in each level. The net had 500 meshes at the mouth and 500 at the cod end of 7.5 mm side. In this paper we refer solely to the samples which provided *M. merluccius* recruits. The hake collected were measured for their total length (TL) to the lower half-centimetre and used as samples of gonads and otoliths. The isolated sagittae were preserved in water. The growth bands were observed with a stereo-microscope in incident light against a dark background and measured by an oculr micrometer; measurements were made along the dorso-ventral axis with the sagitta lying on the lateral side.

RESULTS AND DISCUSSION

Identification of the recruits

It is difficult to determine for how long and for what length/age the fish can be considered recruits. Pereiro and Fernandez (1983) have distinguished as recruits all the hake belonging to the 0 group (from 6 to 16 cm TL in Galicia for the Atlantic *M. merluccius*) dividing the length frequency distributions into age groups on the basis of the growth equation provided by the ICES *M. merluccius* study group; they then indicated on a map the zones where they had found these 0 group fish. In reality, if by nurseries one means the area where the fish grows until it reaches sexual maturity, one would also have to localize fish of a more advanced age. Preliminary observations on reproduction (carried out in Liguria) lead one to believe that

males mature at the age of 3 and females at the age of 4. The catches in the 82/83 programme, carried out with a net of 6 mm sided cod end, enabled us to observe individuals starting from 2.5 cm TL, while the minimum modal length observed in the length frequency distributions was 5 cm (2.6.1983). It is thus likely that we were observing hakes which were really at the beginning of their benthic life.

In the literature, there are observations on very young individuals obtained with trawl nets. Lo Bianco (1909) reported that from March to June in the Gulf of Naples the trawl nets caught individuals of 1.8 -4.5 cm TL; Figueras (1955) records individuals starting from 8 cm TL off the Catalan coast; Larraneta (1970) talks of 7 cm individuals; Boulhal and Ktari (1975) on the Tunisian coasts record some starting from 8 cm; Zupanovic (1968) in the Adriatic starting from 3 cm (minimum mode 6); Jukic and Arneri (1983), who also refer to Hvar's expedition (1948-49), show frequency distributions which include minimum sizes of 4 cm TL (mode 12); in the Eastern Ligurian Sea, Bilio (1969) has also observed minimum lengths of 4 cm (mode 12).

Working on the assumption that the Atlantic hake represents a distinct taxon (Maurin, 1965), we have only considered the Mediterranean hake. Given that the age and growth of hakes in the Ligurian Sea have not yet been the subject of specific studies, it is first necessary to describe the juvenile growth of *Merluccius merluccius* starting from the 0 group.

Times of recruitment and growth in the length/frequency distributions

The 82/83 programme comprised 88 hauls and provided 70 samples of hakes from which were obtained length/frequency distributions. Generally the catches obtained at 50 and 90 metres were useful in distinguishing groups of individuals from the polymodal size/frequency distributions. For the purpose of studying recruitment we dwelt on the first group on the left among those distinguishable in the polymodals, that is, solely on the youngest group that can be separated from the rest using the simple criterion of symmetry of distribution. As will be pointed out later, the fact that the fish in question really formed part of a homogeneous group was also verified using morphological criteria (examination of the sagittae). An interesting temporal sequence is formed by the samples obtained between June and December 1983 (Fig. 2). The groups of recruits collected in an hour's trawl in June and July '83 are absolutely the greatest in number of the «coastal strip» programme and contain a clearly defined cohort of very young fish. In the June sample a mode is evident which is formed of hakes of only 5 cm. They reach 6 cm in July, 7 cm in August, slow down somewhat in September (7.5 cm), and they reach a modal length of 10 cm in December (Fig. 2). Thus, in about 6 months altogether (2/6-8/12) these spring recruits grow by about 5 cm.

Other recruits of comparable sizes to the preceding ones have been observed in winter. Fig. 3 (Jan. 82; Dec. 82; Jan. 83) shows 3 samples which include a wide range of sizes, but which clearly demonstrate groups of young (on the left) whose modal length is only 6-7 cm. If we hypothesize a growth identical to the preceding one - we will see later that the ambient temperature is more or less constant throughout the year - that is, a little less than a centimetre a month, one would have a samole in November with recruits of a modal length equal to 5 cm. Unfortunately, the November catch only provided a small number of individuals.

Other times of recruitment were recorded in which the distributions corresponding to the youngest fish would presuppose the presence of recruits of 5 cm in March and April.

It is thus evident from the samples illustrated that the arrival of recruits on the bottom can happen repeatedly throughout the year, even though in the series of samples studied, the June sample appeared more numerous and was followed in order of importance by the late autumn samples.

Among the series of samples collected in 1985 during the «Evaluation of Demersal Resources» programme, two showed impressive concentrations of recruits: respectively there were 844 individuals with a modal length of 10 cm at 120 metres depth on

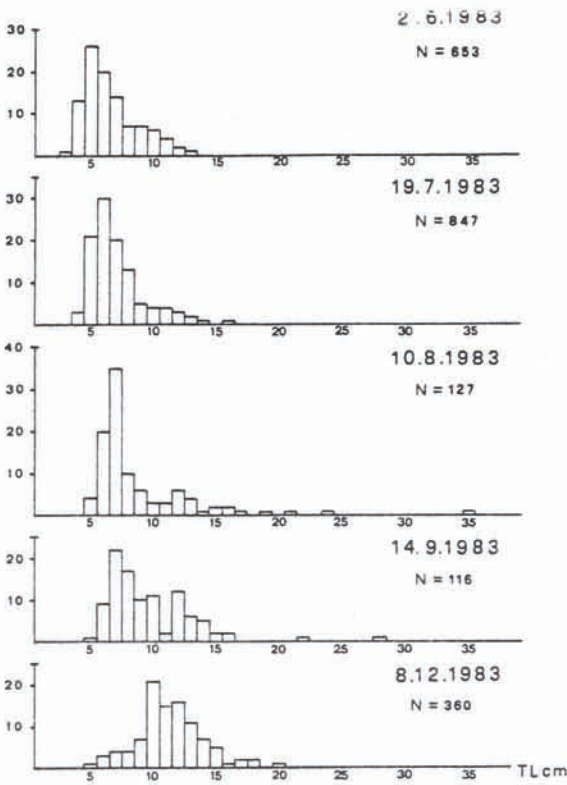


Fig. 2 : Serial length/frequency distributions obtained at 90 m depth.

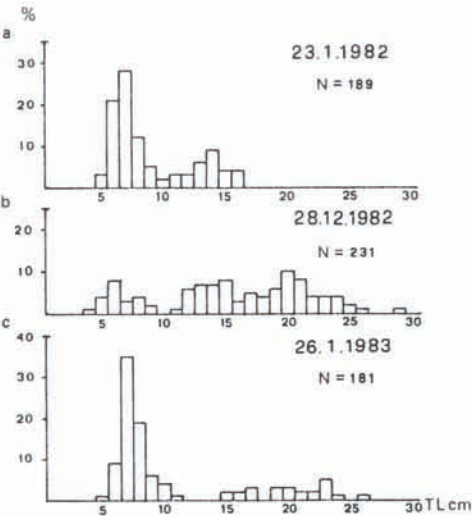


Fig. 3 : Recruits of *M. merluccius* in winter samples (a and c at 90 m ; b at 50 m).

9/9/85 and 673 individuals of corresponding sizes at 200 m depth on 12/9/85. Allowing for these too a growth rate equal to that illustrated in Fig. 2, the recruits of only 5 cm would make contact with the bottom in April.

In summary, it has been found that the main groups of recruits which reach the trawable bottoms of the Ligurian Sea are separated by approximately half-yearly intervals. In fact, there is a spring recruitment (from March to June) and a late autumn recruitment (October-December) within both of which one can sometimes find evidence of distinct sub-cohorts. Those found during the 82/83 programme were followed in their growth for about 6 months (Fig. 4) : growth is indicated by the straight line segments obtained by calculating the mean length/age regression taken from the distinct groups in the frequency polygons using the modalities already referred to. The absolute fage was fixed on the assumption that the recruits were 6 months old when they appear with a mode of 6 cm. The spring ones, therefore, would result from an autumn reproduction and the autumn ones from a spring reproduction.

The differences between the growth rate of the spring and the autumn cohorts were tested by a Student's *t* which was applied to the angular coefficients (*b*) of the regression lines (Scossiroli and Palenzona, 1971), calculated separately for the two cohorts (12 pairs of values for the spring cohort and 5 for the autumn cohort, Fig. 4). The growth rate differs significantly in the two cohorts ($t = 2.22$, d. f. = 13, $p < 0.05$). The confidence limit of the growth rate for the spring cohort ($p = 0.01$) is between 0.832 and 1.164 cm per month ; the corresponding value for the autumn cohort is between 0.718 and 0.936 cm per month.

Since it is useful from a biological point of view to provide a single growth equation for hakes during their first year of life, let us summarize the size/age relations in the total regression (17 pairs of values) : $TL \text{ (cm)} = 0.0311 T \text{ (days)} + 0.3606$ with $r = 0.9855$ and $sb = 0.0024$. According to this equation the fish, on completion of its first year, has an average length of 11.7 cm (range 10.1 - 13.3 cm, at $p = 0.01$). The twofold nature of the recruitment of the Mediterranean hake is a new fact, even if repeated observations agree on the length of the reproductive period. As a matter of fact, there are still many uncertainties about the stages of ovarian maturation and spawning, and comparisons between various areas are often impossible because authors have used different criteria in assessing maturity. The Atlantic *Merluccius merluccius* seems to have a spring recruitment (Decamps and Labastie, 1978) divided up into successive waves, which only recently have been linked to partial ovarian spawning (Sarano, 1984/1986).

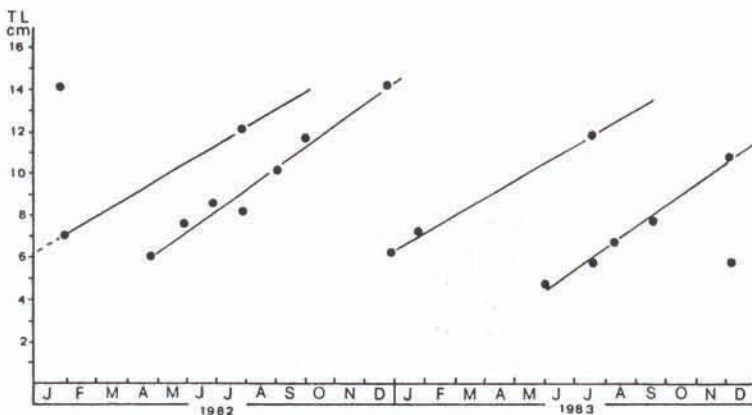


Fig. 4 : Growth of recruits of *Merluccius merluccius* (autumn and spring cohorts).

Morphology of the juvenile sagitta. First annual ring

From the programmes conducted both on the coastal bottoms and on all the trawlable bottoms between Arenzano and La Spezia there has been an outstanding collection of sagittae (approx. 3500 pairs) of very young fish (starting from 6 individuals of the size range 2.5-3 cm) whose growth rings were read.

During the first few months of the hake's life quite prominent hyaline rings are formed which make the subsequent assessment of age difficult. Some are formed during the pelagic phase (Nichy, 1969), others at the moment of descent to the bottom, probably in relation to a change of diet (recruitment ring).

As is known (CGPM, 1982), the key problem in age reading is that of recognising the first annual ring, meaning the first period of growth slowed down for a sufficiently long time to be referred to a season (for the above-mentioned CGPM report this corresponds to the winter season): this ring will constitute the point of departure for subsequent counts.

On the basis of the examination of numerous young sagittae it seemed useful to establish a minimum width for the hyaline ring which would be acceptable as a first annual ring. In this way we sought to replace an inevitably subjective criterion in investigation of a sufficiently prominent ring with a fixed criterion. On the basis of experience acquired with the Ligurian material and of morphological features illustrated in the CGPM report (1982) and in the ICSEAF atlas (1983), the minimum width of the ring was fixed at 200 μ m. In the sequence of the monthly samples of recruits the appearance of this ring was established, making it possible to distinguish two age groups: group 0 and group 1. The appearance of the annual ring was noted as starting from a minimum of 8 cm and with a modal length of 11 cm.

The separation of the age groups 0 and 1 in the samples studied (Fig. 5) confirms the twofold origin of the recruits. The existence of an annual ring at about 11 cm coincides with evaluations of growth carried out by means of back-calculation (Adelbert, 1981). In fact, with system one goes back to the first annual ring. Adelbert (1981) has calculated that the hakes in the Golje du Lion measure 11.2 cm at the age of one year if they are males and 11.6 cm if they are females.

Spatial distribution of 0 group hake

Of the four depth levels systematically explored during the 82/83 programme, only the last two provided appreciable quantities of recruits: the -90 level throughout the year, the -50 level only in the winter months. The 0 group hake stay in a circalittoral strip, while, after the formation of the first annual ring, the young fish venture as much into more superficial as into deeper waters.

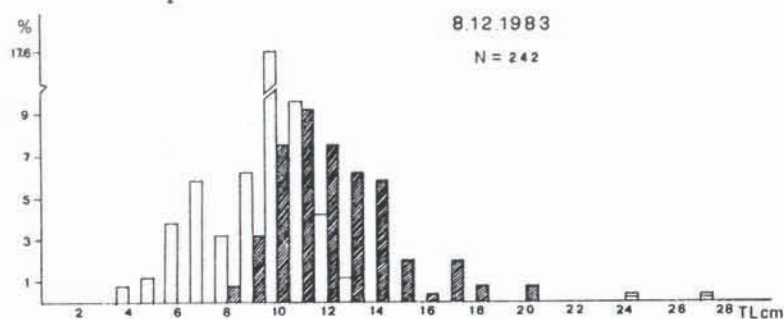


Fig. 5: Separation of two age groups of *M. merluccius* on the base of sagitta readings. In the length/frequency graph the hatched columns represent the fish bearing the first annual ring.

The extensive sampling carried out during the «Evaluation of Demersal Resources» programme confirmed this circalittoral distribution with a maximum lower limit in the transitional zone to the bathyal. The horizontal extension of the nurseries affects the whole area which was explored.

The Ligurian nurseries thus appear somewhat more extensive than those indicated by Zupanovic (1968) or by authors who have subsequently studied the *M. merluccius* of the Adriatic, among whom recently there have been Jukic and Arneri (1983); in this sea the smallest fish were found at 150-210 metres, that is practically confined to a single nursery corresponding to the mid-Adriatic troughs.

Correlation with environmental factors

We have gathered together several hydrological observations (Della Croce *et al.* 1979, 1980) made in proximity to the areas where we have studied recruitment.

The recruits seem to prefer water little influenced by variations in salinity and corresponding to the minimum temperatures on the shelf: even the months of «border-crossing» to only 50 metres are those in the winter when the water column is uniformly cold. The vertical positioning of the recruits is very similar to that ascertained for larvae and post-larvae of the Adriatic hake (Karlovac, 1965): the greatest number of specimens in 69 hauls were taken between 50 and 200 metres (with the 50-100 range predominating slightly) and at temperatures between 12 and 14.5 degrees.

The larvae of the Atlantic hake are located especially between 40 and 200 metres, with a preference for the range 40-80 (Coombs and Mitchell, 1982). The 0 group nurseries in the Gulf of Guascogna and on the Galicia platform are to be found primarily between 100 and 200 m (Pereiro and Fernandez, 1983).

Biological aspects of the nurseries on the Ligurian Riviera have been described; in particular, the associated fauna, as species of commercial interest (Relini *et al.*, 1985; Relini and Orsi Relini, 1984) and as macro-invertebrates, which are indicators of biocoenosis (Cattaneo and Albertelli, 1983; Peirano and Tunesi, 1985).

In summary, the recruits of *M. merluccius* of the Ligurian Sea and, probably in general, of the western Mediterranean basin, make contact with circalittoral bottoms characterised by relatively constant hydrological conditions. The remarkable eurytopicity of the adults, which frequent bottoms from 20 to 1000 metres, is thus something acquired at a later age.

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